MAP GP-424

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AEROMAGNETIC AND GEOLOGIC MAP OF PART OF THE SILVER CITY MINING REGION, GRANT COUNTY, NEW MEXICO

By
William R. Jones, James E. Case, and Walden P. Pratt

GEOPHYSICAL INVESTIGATIONS
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INTRODUCTION

This report presents the results of an aeromagnetic survey of part of the Silver City mining region of New Mexico. Both aeromagnetic and geologic data have been combined in a single map.

The generalized geologic map was compiled from several sources (see map), and largely represents geologic mapping done at scales of 1:20,000 or larger by U. S. Geological Survey personnel between 1948 and 1960. Reports on the Santa Rita, Fort Bayard, and Hurley West quadrangles are now in preparation. A map of the Santa Rita quadrangle at 1:62,500 was published in 1953 (Hernon and others, 1953), and a map of the Central mining district at 1:10,000 was open-filed in 1955.

The aeromagnetic survey was flown in 1946. Measurements of total magnetic intensity were made by a continuously recording AN/ASQ-3A fluxgate magnetometer installed in an AT-11 airplane. Air photographs were used for pilot guidance, and the flight path of the airplane was recorded by a gyro-stabilized continuous-strip camera. Flight lines were spaced from 1/4 to 1/2 mile apart and were flown at approximately 1,000 feet above the surface. The distance from plane to ground was measured by a continuously recording radio altimeter. The magnetic map was compiled by procedures similar to those described by Balsley (1952). Planimetric base maps were used in compilation of the magnetic map, and some magnetic features may be erroneously located by as much as one-eighth mile.

Some of the magnetic anomalies can be correlated with known geologic features, especially those anomalies related to the major magnetite deposits, but a few anomalies of high amplitude cannot be readily explained in terms of known surficial geology and merit more detailed geological and geophysical investigation, as they may be related to concealed deposits of magnetite or magnetite and chalcopyrite.

GEOLOGY

General geologic setting

The Silver City mining region lies on a broad northwest-trending synclinal block, about 15 miles wide and at least 20 miles long, whose bounding sides have dropped (relatively) along major basin-range faults (fig. 1). The syncline consists of Paleozoic rocks, dominantly limestones, and Mesozoic rocks, dominantly shale and sandstone. This broad synclinal structure, however, has been complicated by numerous cross faults, and by complex igneous activity in the Late Cretaceous and Tertiary, during which time the older rocks were intruded by a great variety of igneous rocks including sills, laccoliths, plugs, stocks, and dikes and dike swarms, and in part covered by a large mass of volcanic breccia. The northwest and southeast ends of the synclinal block are now mantled by flat-lying volcanic rocks of Miocene(?) age and by late Cenozoic gravels.

GEOLOGIC FORMATIONS

Precambrian rocks

The Precambrian rocks of this part of the Silver City region comprise only a few small outcrops of granite and quartzite, representing the crystalline basement complex on which the Paleozoic sediments were deposited. Because of their small areal extent and their probable lack of influence on the aeromagnetic pattern, the Precambrian rocks are grouped with the Paleozoic rocks on the geologic map.

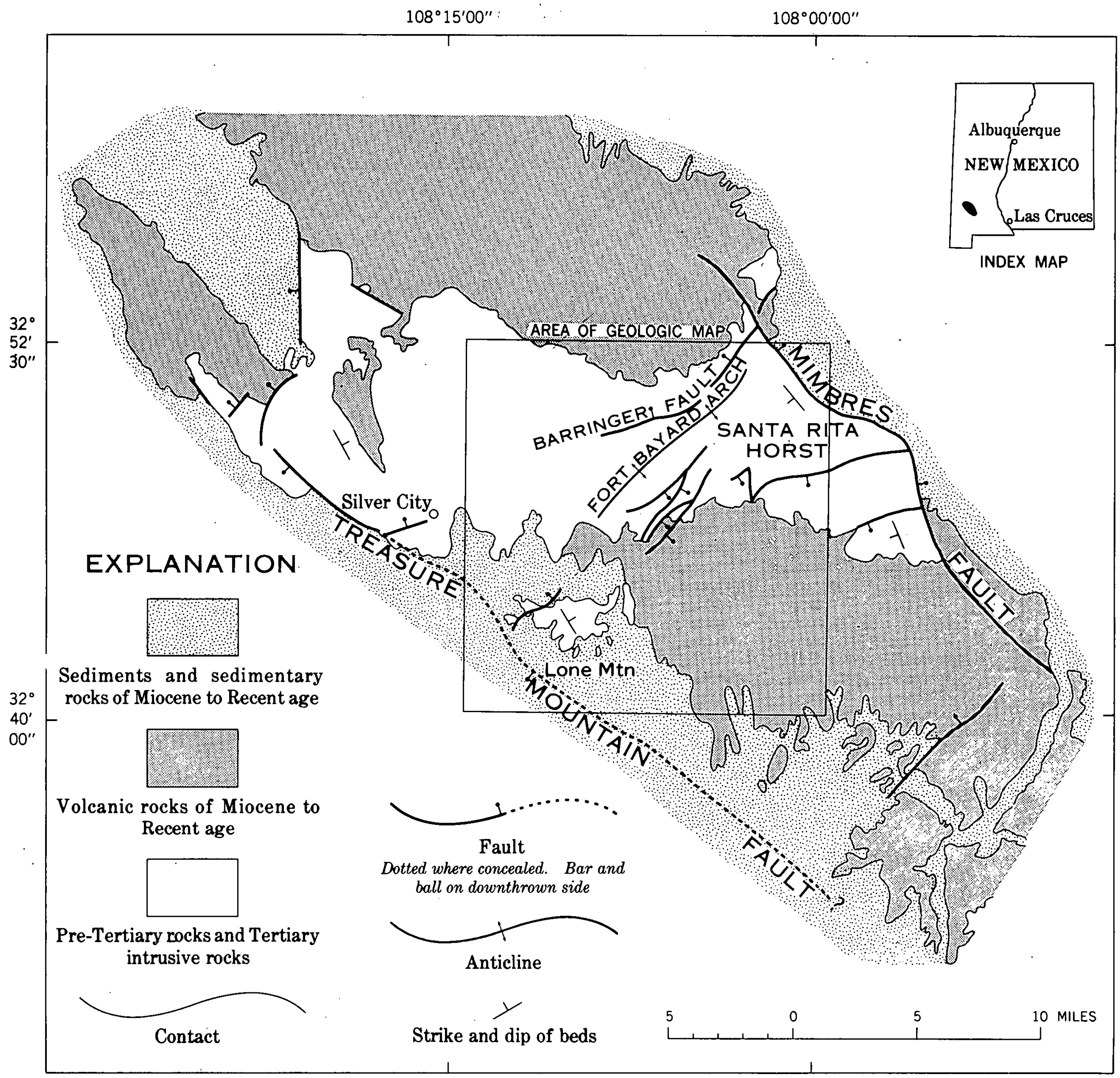
Paleozoic and Mesozoic rocks

Sedimentary rocks representing the Cretaceous System and all systems of the Paleozoic are exposed in the area. Rocks of Triassic and Jurassic age are not present. The Paleozoic section is about 3,300 feet thick and consists chiefly of limestone and dolomite, with minor amounts of shale, mudstone, and sandstone. The Cretaceous section consists of about 1,800 feet of sandstone and shale. Details of the stratigraphy have been described elsewhere (Hernon and others, 1953; Pratt and Jones, 1961a); they are summarized in table 1.

Mesozoic and Early Cenozoic Igneous rocks

Some 30 or more distinct varieties of igneous rocks, mostly intrusive, were emplaced during the interval from Late Cretaceous to Miocene time. These rocks are assignable to four age groups, which are, from oldest to youngest:

1. Generally concordant plutons--thin and thick sills, laccoliths, and bysmaliths.
2. Mafic plugs and dike swarms spatially and temporally related to mafic flows and breccia.



Modified from Jones and others (1961) and Dane and Bachman (1961)

FIGURE 1. STRUCTURAL GEOLOGIC SETTING OF THE SILVER CITY REGION, GRANT COUNTY NEW MEXICO

Table 1.— *Paleozoic and Mesozoic sedimentary rocks in the Silver City region*

Age	Formation	Lithology	Approximate maximum exposed thickness (ft)
Late Cretaceous	Colorado Shale	Interbedded sandstone and shale	1,650
Late(?) Cretaceous	Beartooth Quartzite	Massive orthoquartzite, minor shale	140
		— Unconformity —	
Early Permian	Abo Formation	Red calcareous mudstone and shale	265
Pennsylvanian	Syrena Formation	Gray limestone, silty in part; thick shale lenses in lower part.	350
Pennsylvanian	Oswaldo Formation	Massive limestone; shale bed at base	420
		— Disconformity —	
Mississippian	Lake Valley Limestone	Slabby to massive limestone; chert lenses in many beds.	480
Late Devonian	Percha Shale	Upper part: shale with limestone nodules Lower part: black fissile shale	410
		— Disconformity —	
Silurian	Fusselman Dolomite	Massive dolomite	300
Late Ordovician	Montoya Dolomite	Dolomite; interbedded chert in middle part; sandstone at base.	350
		— Disconformity —	
Early Ordovician	El Paso Dolomite	Slabby dolomite and limestone	520
Ordovician and Late Cambrian	Bliss Sandstone	Dark massive orthoquartzite locally hematitic or glauconitic; minor dolomite.	190
		— Unconformity —	
Precambrian		Granite, quartzite	

3. Discordant plutons--stocks and apophyses and upward-flaring masses.

4. Dominantly silicic dike swarms and plugs.

For the purpose of the geologic map the igneous rocks are grouped primarily according to composition--mafic to intermediate (gabbro to syenodiorite) versus silicic (quartz diorite to granite)--and form. These compositional groups show a general correspondence to the age groups, but there are a few exceptions, as noted. The compositional groups are listed below; numbers correspond to the numerical subscripts on the geologic map.

A. Silicic concordant plutons (age group 1):

1. Hornblende quartz diorite.
2. Quartz diorite porphyry.
3. Fort Bayard laccolith and Hurley sill (distinct bodies where exposed but probably continuous beneath cover)--hornblende quartz diorite and hornblende latite porphyry.

4a. Cameron Creek laccolith--biotite-quartz latite porphyry.

4b. Chino Quarry sill--biotite latite.

B. Mafic volcanic rocks: andesite breccia, agglomerate, and mafic flows (age group 2).

C. Mafic to intermediate plugs, stocks, and sills; thousands of mafic porphyry dikes, whose density and general trends are indicated by green hachures on the geologic map (predominantly of age group 2).

5. Gabbro-diorite stock and irregular masses of pyroxene porphyry.
6. Igneous complex of gabbro and pyroxene porphyry plugs and dikes, boundaries indefinite.
7. Intermediate plugs--diorite and syenodiorite.
8. Intermediate sills--syenodiorite (age group 1).

D. Silicic discordant plutons (mostly of age group 3) and silicic dikes and plugs (age group 4) (most of the silicic dikes are too small to show on the geologic map, but a few are shown to indicate their general trend):

9. Pinos Altos stock and apophyses--hornblende quartz monzonite.
10. Hanover-Fierro stock--granodiorite--quartz diorite porphyry.
11. Santa Rita stock--quartz monzonite--granodiorite porphyry.
12. Copper Flat pluton--quartz latite porphyry.
13. Rhyolite porphyry plugs and related tuffs of middle Tertiary age (younger than age group 4).

More detailed descriptions of these igneous rocks and the deformation and metallization related to them have been published recently (Jones and others, 1961; Pratt and Jones, 1961b).

Late Cenozoic rocks

Rocks and sediments of late Cenozoic age underlie the north and south margins of the area; they comprise flat-lying flows, tuffs, ignimbrites, and intercalated sandstones and conglomerates of Miocene (?) to Pliocene age, and relatively unconsolidated valley-fill gravels, alluvium, and landslide debris of Pliocene(?) to Recent age. The volcanic rocks include rhyodacite flows, rhyolitic to quartz latitic tuffs and ignimbrites, and basaltic andesite flows. The silicic volcanic rocks and the interbedded sedimentary rocks are grouped on the geologic map with the gravels and alluvium, but the basaltic andesite flows are shown separately because of their greater magnetiszation.

GEOLOGIC STRUCTURE

The gross structure of the Silver City region is a broad northwest-trending syncline contained within a northwest-trending regional horst (fig. 1). This horst is bounded on its northeast side by the Mimbres fault and on its southwest side by the Treasure Mountain fault. Within the regional horst, the broad northwest-trending syncline is modified by many structures directly or indirectly related to the injection of sills, laccoliths, stocks, and dikes during the interval between Late Cretaceous and Miocene(?) time. Four periods of deformation are recognized: (1) doming and some faulting accompanying the intrusion of sills and laccoliths; (2) extensive normal faulting during the time between the intrusion of sills and the intrusion of stocks; (3) folding and some faulting related to the forceful intrusion of magma that expanded at shallow depths to form funnel-shaped stocks; and (4) faulting and fracturing during the extended epoch of dike emplacement.

The chronological order of development of faults in post-Miocene(?) time is imperfectly known. Faults developed intermittently during deposition of the Miocene(?) volcanic rocks, and several of these resulted from reactivation of pre-Miocene faults. Some basin-range faults of the region may have developed soon after Miocene (?) volcanic activity and others during the late Tertiary and early Quaternary, when the valley-fill gravels were being deposited. Late movement on the Mimbres fault displaces the valley-fill gravels, and may be of late Pleistocene age.

ORE DEPOSITS

Several mining districts containing a variety of metalliferous ores are within the limits of the area. The most productive districts are close to silicic discordant plutons--stocks, funnel-shaped masses, and dikes. Major deposits of magnetite-chalcopyrite ore are in carbonate rocks close to the margins of the Hanover-Fierro (TKd_{10}) and Santa Rita (TKd_{11}) plutons. Sphalerite ores containing some galena, chalcopyrite, and magnetite are in carbonate rocks between Hanover and Santa Rita, and around Santa Rita, and around the south lobe of the Hanover-Fierro pluton (TKd_{10}). Sphalerite-galena and sphalerite-galena-chalcopyrite ores occur in veins and replacement bodies along major faults (such as the Groundhog and Barringer faults), along most granodiorite dikes in the Santa Rita quadrangle, and around the small Copper Flat pluton (TKd_{12}). Great volumes of low-grade chalcopyrite-chalcocite ores, but locally enriched, containing some molybdenite, are found within the Santa Rita stock (TKd_{11}) and older rocks adjacent to it. Close to and within parts of the relatively large Pinos Altos stock (TKd_9) are narrow quartz veins containing principally sphalerite and galena, some chalcopyrite, and trace amounts of gold and silver. West of Pinos Altos, about 1 mile west of the stock, sphalerite replacement deposits occur in limestones of Pennsylvanian age.

Silver and lead ores were mined from manto-like replacement bodies in dolomite of Silurian age in the Georgetown district, located in the northeastern part of the Santa Rita quadrangle, about 3 miles east of the Hanover-Fierro pluton. The Lone Mountain district, located about 8 miles southwest of the Santa Rita stock, has yielded silver and manganese ores from fissures and small replacement deposits in lower Paleozoic dolomites and limestones.

The igneous and deformational history of the area up to the time of primary metallization has been summarized recently (Jones and others, 1961). The main epoch of primary metallization followed the emplacement of the discordant plutons, and, at least in the Santa Rita quadrangle, the emplacement of a swarm of granodiorite dikes. The hypogene fluids are believed to have risen along the margins of the stocks and obliquely up faults and bedding planes intersecting those margins.

The massive magnetite replacement deposits are the only ores that are reflected in the aeromagnetic survey, and therefore are the only deposits located on the geologic map.

INTERPRETATION OF THE MAGNETIC ANOMALIES

Many of the magnetic anomalies in the region can be readily correlated with surficial geology, but a few are evidently related to buried geologic features.

The most prominent magnetic anomalies include magnetic highs related to magnetite deposits at Fierro and Santa Rita, and a large crescentic high with prominent peaks overlying the complex of igneous rocks south of Pinos Altos.

The horseshoe-shaped high of 600 to 1,000 gammas at Fierro overlies replacement deposits of magnetite that are found in Paleozoic dolomites around the periphery of a granodiorite stock. The areal extent of the high coincides almost exactly with that of known iron deposits. Local discordance of the iron deposits and magnetic highs can be attributed in part to the position of the flight lines, in part to lower susceptibility of the deposits, and in part to size of the deposits. Obviously, such replacement-type magnetite deposits of commercial tonnage have good magnetic expression.

The isolated magnetic high of about 500 gammas just west of the Fierro anomaly overlies the southeastern end of a sill-like syenodiorite intrusion at Hermosa Mountain. Inasmuch as the bulk of the intrusion shows only slight magnetic effects north of Hermosa Mountain, we infer that the high results from local concentrations of magnetite rather than from the overall or "background" magnetization of the syenodiorite. Estimates of the depth of the source of the magnetic anomaly range from 1,000 to 1,500 feet below the flight elevation, or, from the ground surface to 500 feet below the surface near the central portion of the anomaly. Bedrock exposures beneath this anomaly were examined in the field and a deposit of magnetite replacing syenodiorite was found about 800 to 1,000 feet southeast of the center of the anomaly. The magnetite deposit is shown as a small dot "A" on the geologic map. The exposed magnetite deposit is only about 15 feet in diameter and is too small to account for the total magnetic anomaly at Hermosa Mountain. It may therefore be inferred that a larger magnetite deposit exists at shallow depth beneath the anomaly, either in the syenodiorite or in the underlying strata.

A magnetic high of about 400 gammas is found over the Santa Rita quartz monzonite stock. Superimposed on this relatively broad high are a series of smaller highs of steep gradient and large amplitude arranged in a crescentic pattern around the periphery of the stock. The northern group of highs are generally related to known magnetite deposits containing significant amounts of chalcopyrite; the largest high of the group overlies shallow magnetite deposits adjoining the northwest margin of the stock, and the two highs of smaller areal extent, located along the northeast margin of the stock, also overlie known magnetite deposits in the Abo, Syrena, and Oswaldo Formations. The two magnetic highs of lower amplitude, located southeast of exposed parts of the stock, overlie Quaternary landslides and mine dumps; these highs are probably related to magnetite deposits buried at relatively shallow depth.

Magnetic lows centered over the Hanover-Fierro and Santa Rita stocks are partly apparent or residual lows resulting from the surrounding crescentic magnetic highs over the magnetite deposits. Material of relatively low susceptibility is probably responsible for the closed low near the central portion of the Santa Rita stock. Note that the magnetic values in the lows are still several hundred gammas higher than regional values away from the stocks.

The large northwest-trending magnetic low northeast of the Santa Rita stock is mainly a polarization low generated by the magnetic bodies near the stock. Evidently the magnetite deposit just north of Santa Rita, which occurs in the polarization low, is too small to produce a measurable magnetic effect 1,000 feet above the surface.

A pair of small, sharp magnetic highs and lows in the southeastern part of the surveyed area are related to basaltic andesite flows. Irregular, discontinuous, isolated anomalies of this type are characteristic of other basalt flows in the western United States.

The dominant magnetic anomaly in the northwestern part of the area is a large crescentic magnetic high, concave to the northeast, located from 2 to 5 miles south and southeast of Pinos Altos. The anomaly on the northwestern limb of the crescent ranges from 1,000 to 1,500 gammas and that on the southeastern limb ranges from 400 to 800 gammas.

The southwest and southeast margins of the large crescentic anomaly locally coincide with the limits of a deposit of andesite breccia. From the settlement of Whiskey Creek northeastward to the region west of Hermosa Mountain, the magnetic contours closely follow the northeast-trending contact between the andesite breccia and the Colorado Shale. The amplitude of the anomaly across the contact ranges from less than 100 gammas to more than 400 gammas. From Whiskey Creek southwestward, however, the margin of the anomaly lies about one-half mile southeast of the probable extension of the contact between the andesite breccia and the Colorado Shale. The magnetic gradient in this section amounts to about 800 gammas in 1 mile.

The magnetic contours along the southwest margin of the crescentic anomaly parallel the contact between the andesite breccia and the Colorado Shale for some distance, but the 2,100 gamma contour, which marks the base of a steep magnetic gradient, lies about 3,500 feet southwest of the contact. Elsewhere the magnetic contours cross the same contact at about right angles. Thus, although the andesite breccia may contribute a few hundred gammas to the background magnetic field, the outline of the significantly anomalous area is not, in our opinion, primarily related to the distribution of the breccia.

Inspection of the aeromagnetic map clearly reveals that the steep gradients of this anomalous area do not coincide with the contacts between any of the exposed mafic or intermediate plutons or with the swarm of mafic porphyry dikes. Portions of individual mafic intrusions underlie the major magnetic highs and extend under adjacent magnetic lows. Similarly only a relatively small portion of the mafic porphyry dike swarm underlies the magnetic high.

Vertical intensity anomalies range from 500 to 7,000 gammas or more over various rock types in ground traverses made at the site of the aeromagnetic high. In some cases, very large ground magnetic anomalies are found directly over segments of individual dikes but low anomalies are found immediately off the dikes or along their trend. In contrast, no significant ground magnetic anomalies are found over petrographically similar dikes exposed along U. S. Highway 270 about 1 mile south of the aeromagnetic high. Generally high and erratic ground magnetic anomalies are detected over mafic intrusions (TKm_6) west of Whiskey Creek.

These facts indicate that neither the rocks of the mafic plutons nor the mafic porphyry dikes are uniformly magnetized. It is only within the area of the large crescentic anomaly that the surficial rocks contain appreciable segregations of magnetite. Does the large aeromagnetic anomaly reflect a multitude of near-surface segregations of magnetite in numerous rocks, or does it reflect the presence of a buried magnetite-rich pluton? Depth estimates from aeromagnetic data at various places on the anomaly suggest that the sources of the anomaly range from near the ground surface, at a point 2½ miles southeast of Pinos Altos, to 1,500 feet or more below the surface at points along the southern margins of the anomaly.

The gabbroic plutons and the swarm of pyroxene porphyry dikes in this area may have been derived from a large underlying gabbric magma. In differentiating, magnetite may have been concentrated in a portion of the magma chamber. Thus, magmas rising from this portion would carry some of the segregated magnetite. Alternatively, the exposed plutons and dikes may have passed through an earlier formed magnetite-rich pluton, incorporating parts of it in the process. A mile south of Pinos Altos there is a small exposure of pyroxenite containing about 10 percent magnetite, and adjacent to it is a rock consisting of pyroxene and labradorite and considerable magnetite. A large buried mass of such material may be the source of the anomaly.

Elsewhere in the region, discontinuous highs and lows of small relief may be related to intrabasement magnetic contrasts, to relief on the basement surface, or to small masses of volcanic or intrusive rocks at shallow depths.

Several magnetic anomalies in the region merit more detailed magnetic surveys to provide precise location and correlation with geology. These are the magnetic highs at Hermosa Mountain, at the ridge 2½ to 3 miles southeast of Pinos Altos, and at the site of the two southernmost aeromagnetic highs near the southeastern border of the Santa Rita Stock. These anomalies are probably related to magnetite deposits. Systematic ground magnetic surveys, sample collection, and possibly drilling should be carried out over the area of the crescentic magnetic high south and southeast of Pinos Altos to determine if a segregation or replacement deposit of magnetite exists at relatively shallow depth.

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